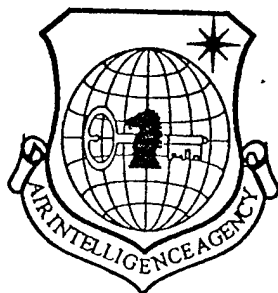# NATIONAL AIR INTELLIGENCE CENTER

EXPERIMENTAL INVESTIGATION OF IMPULSE RADAR FOR
MITIGATION OF EFFECTS OF RADAR ABSORBING MATERIALS

by

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EXPERIMENTAL INVESTIGATION OF IMPULSE RADAR FOR MITIGATION OF
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He Jianguo Lu Zhongliang Su Yi

ABSTRACT

     This article uses experimental methods from the two
areas of frequency-domain and time-domain to investigate
electromagnetic scattering associated with targets coated with
wave absorbent materials. Results clearly show that UWB signals
have a 10-12dB advantage coping with targets coated with wave
absorbent materials as compared to the narrow band signals of
conventional radar. The explanation is that ultra wide waveband
signals clearly possess excellent capabilities for countering
narrow band wave absorbent materials.

     Key Words radar, radar signal, absorbing material, UWB
radar, impulse response
     Classification No. TN958

     The relative frequency band of UWB radar emission signals is
0.8-1. Impulse radar is one representative type of them.
Comparing this type of ultrawide band radar and conventional
narrow band radar, it possesses the following advantages:
extremely high resolution; ability to obtain extremely abundant
target characteristics information; ability to use it in target
classification and recognition, as well as capabilities to
counter wave absorbent materials, and so on. As far as UWB radar
anti-radar wave absorbing material (RAM) characteristics are
concerned, theoretical and experimental research status reports
are extremely few. We made use of impulse radar experimental

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     * Numbers in margins indicate foreign pagination.
  Commas in numbers indicate decimals.

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systems and carried out experimental research on conduction plates and square columns coated with wave absorbent materials. Data associated with returning wave signals was recorded, solving for the impulse response and frequency spectrum associated with targets. In conjunction with this, taking results and frequency-domain results and comparing, it clearly proves the excellent counter RAM capabilities which UWB radar possesses.

1. Frequency Domain Test Systems and Their Results

In order to compare responses to impulse pulses associated with targets coated with wave absorbing materials and good conductor targets and to study wave absorbing material similarities and differences with pulse signals and stable sine signals or narrow band signal absorption, we made use of two methods--frequency domain method and time domain method-- to carry out experimental research. The targets we made use of for experimental measurements were 60x60cm flat plates and 20x20x80cm square columns. Each type of target had two configurations--those having coatings of wave absorbing materials and those not having coatings of wave absorbing materials. The nomenclature of the wave absorbing material was CAH-13.6. It is a rubber plate with a thickness of 3mm. The block diagram for target frequency domain measurements and tests is as shown in Fig.1. The receiving system is a SERIES II EMI test measurement system from the U.S. EATON Company. The whole system does automatic measurements and test with computer control. Fig.2 gives the results for plate measurements and tests. Curve 1 is reception field strengths without coatings of wave absorbing materials. Curve 2 is reception field strengths with coatings of wave absorbing materials. It is possible to see that, within the 2.0-2.5GHz range, attenuation of wave absorbing materials on sine signals is approximately 15dB. In other frequency ranges, there is also approximately 8dB attenuation.

2. Time Domain Experimental Systems

Time domain experiments opt for the use of impulse radar test systems. The block diagram is as shown in Fig.3. Emitting antennas and receiving antennas are double circular cone types. Feeder systems and antenna terminals all opt for the use of special matching, causing the antennas to have excellent time domain characteristics. The impulse pulse generator is an R-100IMP generator from the Omin-Wave Company. The performance indices are rise time 100PS (10-90%), pulse width (-3dB) 150PS, output amplitude 1000V. The maximum frequency range which can be used with the pulse source in question reaches 3GHz. The sampling oscilloscopes are a U.S. Tek 7904 and an SAS-601B from the Japanese Iwaosaki Company. The frequency band is DC-12. 4GHz, sensitivity of 3-5mV. At low repetition frequencies, SAS-601B operations are more stable than Tek 7904 and Tek 7834. Recording and processing equipment is of our own test /47 manufacture. Solutions were found for synchronization problems between signal sources, sampling oscilloscopes, and microcomputers.
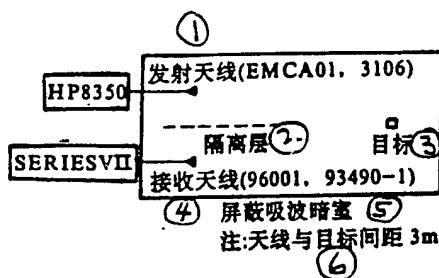

Fig.1 Frequency Domain Test Measurement Block Diagram

Key: (1) Emiting Antenna (2) Isolation Layer (3) Target
(4) Receiving Antenna (5) Shielded Wave Absorption Dark Room
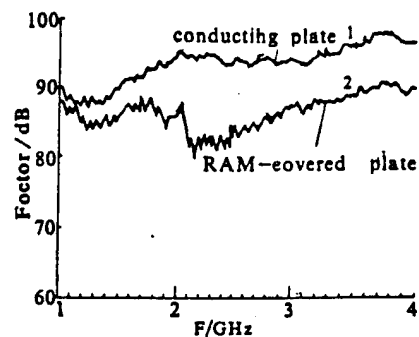(6) Note: Distance Between Antenna and Target 3m
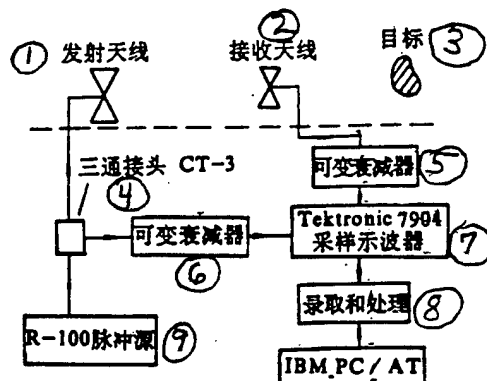
Fig.2 60x60cm Plate Test Measurement Results

Fig.3 Time Domain Test Measurement System Block Diagram

Key: (1) Emiting Antenna (2) Receiving Antenna (3) Target
(4) Three Way Coupling (5) Variable Attenuator (6) Variable
Attenuator (7) Sampling Oscilloscope (8) Recording and
Processing (9) Pulse Source

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    (a) Column Target   (b) Plate Target

Fig.4 Receiving Antenna and Target Placement

    Receiving antenna and target rack are set up inside a
microwave darkroom. All other equipment is located on the
microwave darkroom lower level, as much as possible avoiding the
effects of background scattering on measurements. Receiving
antenna and target placement was as shown in Fig.4. The targets
being measured were 60x60cm aluminum plates, 20x20x80cm hollow
aluminum square columns, as well as target coatings of wave
absorbing materials on plates and columns.

    Experimental procedure was as follows: (1) in situations
where no target exists, record waves directly received by
receiving antenna as well as background scattering waves, remove
all the background, and use; (2) in situations where metal
targets exist, measure directly arriving waves, background
scattering waves, as well as target scattering waves; (3) use
targets coated with wave absorbing materials to replace metal
targets and repeat procedure (2) measurements. Take metal target
response and take out background response when there was no
target. Then, obtain the scattering echo waveforms associated
with metal targets. In the same way, take responses for targets
having coatings of wave absorbing materials and take out
responses when there are no targets. Then, obtain echo waveforms
for coated targets. Through processing of such data as power

spectrum estimates and echo energy calculations, it is possible to compare the differences between echo energies of pulse signals against metal targets and coated targets.

3. Time Domain Experiment Results and Analysis

Measurements were carried out on the two target groups of square plates and square columns. On the measurement data which appeared for square plates, a simple analysis and calculations were done. Fig.5 and Fig.6 respectively are photos of received waveforms with metal plates and when plates are coated with wave absorbing materials. In these, Fig.(a)'s are background /48 waveforms. Fig.(b)'s are waveforms when there are targets. After going through background cancellation processing, one gets their scattering echos as shown in Fig.7. FFT calculations are carried out on the two waveforms of Fig.5(b) and Fig.6(b), obtaining their power spectra as shown in Fig.8. It can be seen that differences between the two are extremely small. It is only in the vicinity of the central frequency for wave absorbing materials. 2GHz that there is a hole. The maximum difference value is 6bB. Fig.2 frequency domain results clearly show that, in a relatively narrow frequency band, the two have relatively large difference values. The maximum values reach 15dB. Because locations including target information lie between 80-300 sampling points, we use methods such as those which follow to calculate energies for the two waveforms of Fig.7. Letting $X_p(n)$ and $X_R(n)$ respectively stand for sampling values associated with metal targets lacking RAM and metal targets with RAM, E_P and E_R stand for their energies. Thus,

$$E_P = \sum_{n=80}^{300} X_P^2(n)$$

$$E_R = \sum_{n=80}^{300} X_R^2(n)$$
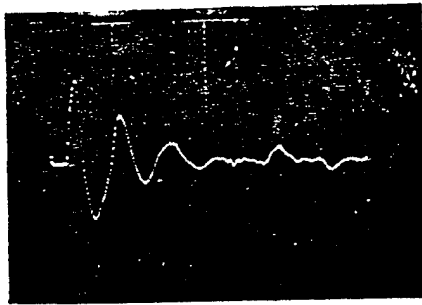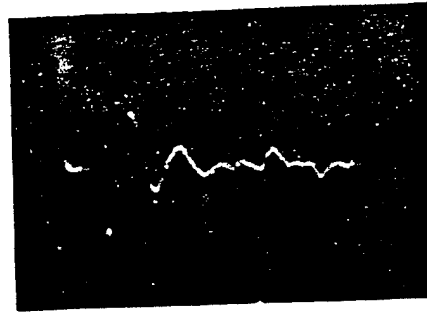
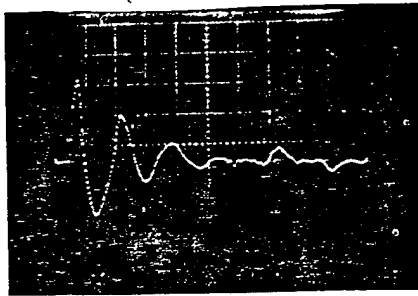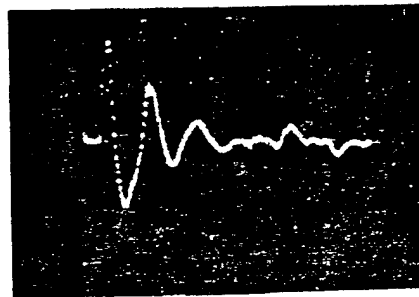(a)   (b)

Fig.5   60x60cm Metal Square Plate Echoes

(a)   (b)

Fig.6   Echoes from Square Plates Coated with Wave Absorbing
Materials

Through carrying out calculations on recorded data, one
obtains RAM relative attenuation of impulse signals as

$$L_{impulse} = 10\lg \frac{E_R}{E_P} = -1.1046dB$$

Considering the measurement results of Fig.2--speaking in
terms of conventional narrow band radar--the normal wavelength is
15%. If one takes the central wave absorbing material frequency
2.2GHz to be the central radar frequency, comparing RAM types,
within the bandwidth considered, attenuation values for the
various frequency points are as shown in Table 1.

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Table 1

f (GHz)	2	2.1	2.2	2.3	2.4
1 无 RAM (dB)	94.6	94.3	94	94.4	93.5
2 有 RAM (dB)	85.7	79.7	80.5	81.3	81.2
3 差 (dB)	8.9	14.6	13.5	13.1	12.3

Key: (1) without   (2) with   (3) difference

Because of this, average attenuations for sine signals were   /49

$$L_{正弦}^{①} = (8.9 + 14.6 + 13.5 + 13.1 + 12.3)/5 = 12.4 dB$$

(Key to equation above: (1) Sine)

We took attenuation differences for sine and impulse signals against the two types of targets with RAM and without RAM and made them the measure of counter RAM capability, that is,

$$C = L_{正弦}^{①} - L_{冲激}^{②} = 12.4 - 1.1 = 11.3 dB$$

(Key to equation above: (1) Sine   (2) Impulse)

From this, it can be seen that impulse signals on a target with RAM can obtain a better than 10dB advantage.
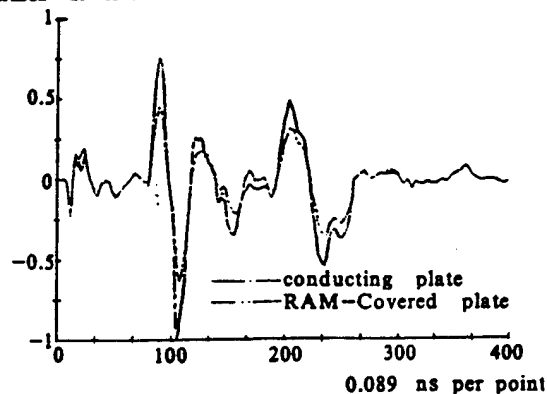

conducting plate
RAM-Covered plate

0.089 ns per point
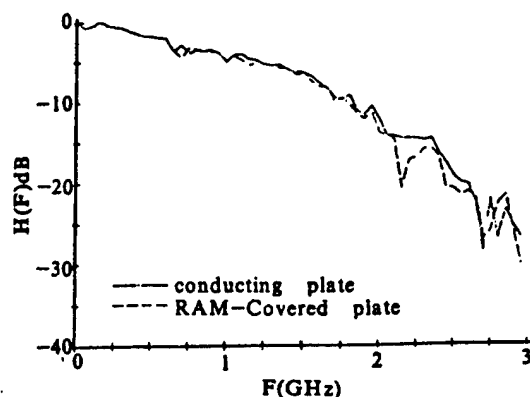
Fig.7   Scattering Echos Associated with Plates

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Fig.8 Power Spectra Associated with Plate Echos

4. Conclusions

(1) Under conditions with impulse signal pulse widths equal to 0.15ns and RAM as CAH-13.6, the relative attenuation $L_{impulse}$ of RAM on impulse signals is 1.1dB. Moreover, average attenuation L_{sine} for RAM on sine signals (2-2.4GHz) is 12.4dB. Therefore, impulse radar counter RAM (CAH-13.6) capabilities are better than those for sine wave radars by 11.3dB.

(2) From Fig.8, one can see that RAM absorption of impulse electromagnetic waves is only relatively large in a narrow band in the vicinity of 2.2GHz. In low frequency areas, there is basically no absorption. In high frequency areas, there is absorption, but it is relatively small. Therefore, appropriate increases in impulse pulse widths will have even better counter RAM capabilities.

(3) Based on the results associated with Fig.2 and Fig.8, RAM absorption of impulse electromagnetic waves is very small-- approximately 1.1dB. If RAM absorption capabilities selected for use are increased, the difference value $\Delta L = L_{sine} - L_{impulse}$ will also increase. That is, impulse radar counter RAM capabilities will be even better than sine wave radar.

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(4) Comparing Fig.2 and Fig.8, they have very large differences. On the basis of this, we recognize that taking frequency as the basis of analysis techniques is certainly not capable of explaining relevant pulse phenomena. When relative signal frequency bands reach 0.8-1, such electromagnetic phenomena as target scattering and propagation will give rise to major variations.

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